MEG II 実験の背景事象の抑制に向けた超低物質量RPCの設計に関する研究

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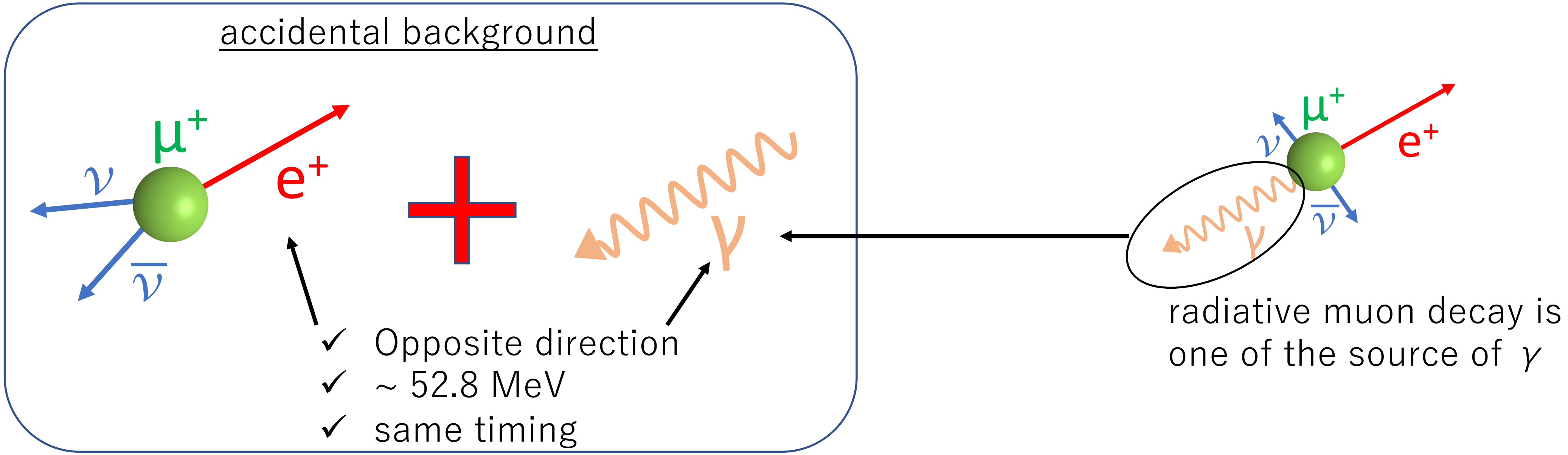
Core-to-Core Program

Contents

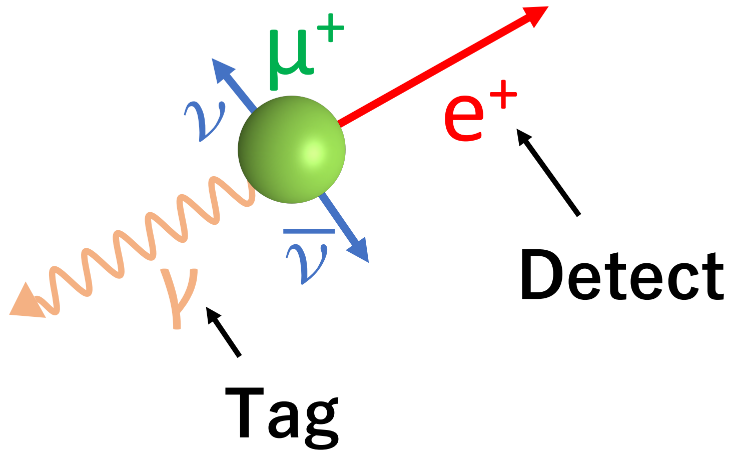
MEG II signal and background

- MEG II will search for $\mu \rightarrow e\gamma$ decay
  - Identified by energy, timing and direction of e and γ

- Dominant source of background is accidental coincidence of BG-e and BG-γ mimicking the signal
  - One of the dominant source of BG-γ is radiative muon decay

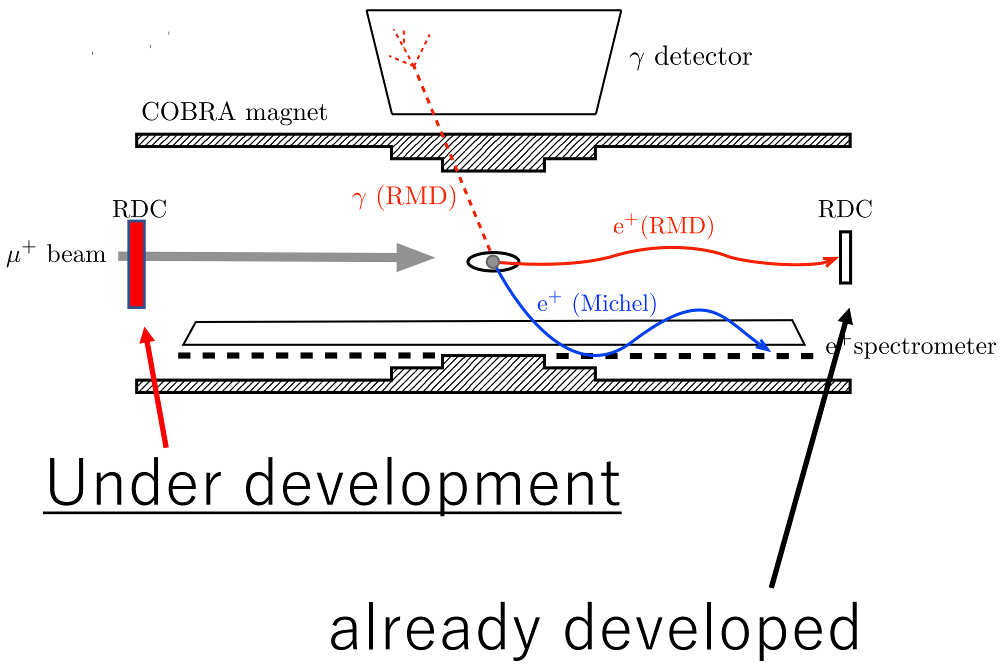


Background identification detector



- New detectors to **tag BG-γ** from radiative muon decay
  - **Detect low energy positron** (1-5MeV) accompanying BG γ (~53MeV)

- Planned to be installed to 2 points
  - Upstream and downstream of the target
  - MEG II sensitivity
    - ➢ 10% improvement with upstream
    - ➢ 15% improvement with downstream
  - Upstream one is under development → Today's talk



Requirements to the upstream detector

1. Material budget: $< 0.1\%\ X_0$ (beam must pass through the detector)
2. 90% efficiency for 1-5MeV positron
3. 1 ns timing resolution
   (RMD identification with the timing difference b/w positron & γ)
4. Rate capability and radiation hardness
   ($10^8\ \mu$/s with 21 MeV/c , >60 weeks run)
5. Detector size: 20 cm in diameter (45% acceptance…total 90% incl. DS)

→ Candidate: Ultra low-material RPC detector using Diamond Like Carbon (DLC)

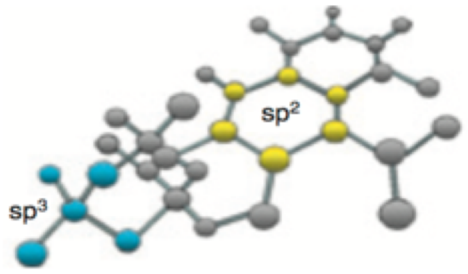
RPC based on DLC technology

RPC performance in general
- time resolution < ns
- material: 1% X_0 → must be improved
- Efficiency ~90% → still requires study
- rate ~kHz/cm^2 → must be improved

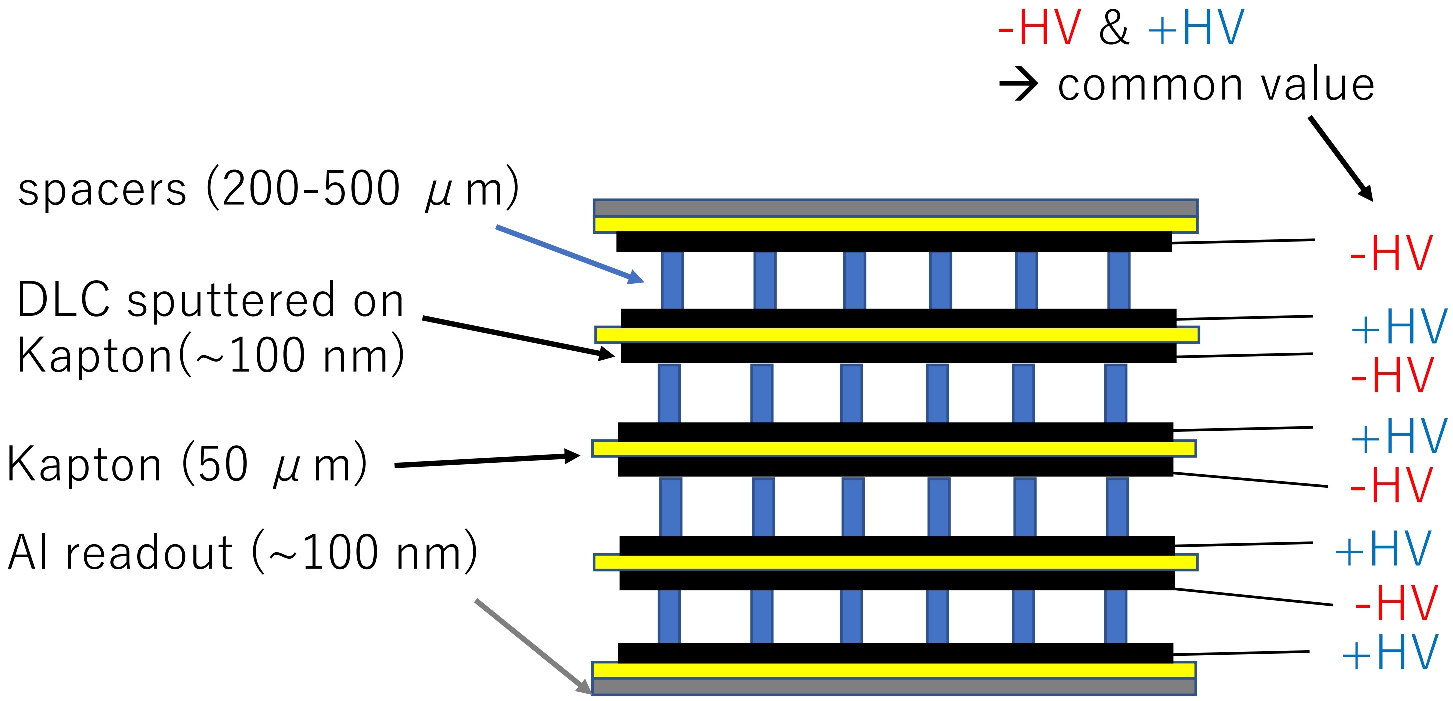
- **RPC:** Gaseous detector with high resistive electrodes placed face to face
  - Gas: R134a (Freon) based
  - Gap thickness: 200 μm—2 mm

- Diamond Like Carbon is used for resistive electrodes
  - DLC: high resistive material w/ mixed structure of sp^2 bond and sp^3 bond
  - Advantages of DLC
    1. low material → Sputter DLC on 50 μm Kapton
    2. Adjustable resistivity
       → Resistivity must be optimized for high rate environment
       (Resistivity must be low to achieve high rate capability)
  - Development initiated by a group of Kobe Univ

DLC: chemical structure



Proposed design of RPC for MEG II



- Readout: Al
  → aluminized Kapton will be used on the top & bottom

- High efficiency can be achieved by multilayer design
  - n-layer efficiency: $\epsilon_n = 1 - (1 - \epsilon_1)^n$
  - From requirement on material budget, 4 layer at maximum

<u>Material budget</u>

- Kapton 50 μm → 0.018 % X_0
- Al 100 nm × 2枚 → 0.0023 % X_0

→ < 0.1 % X_0 is satisfied

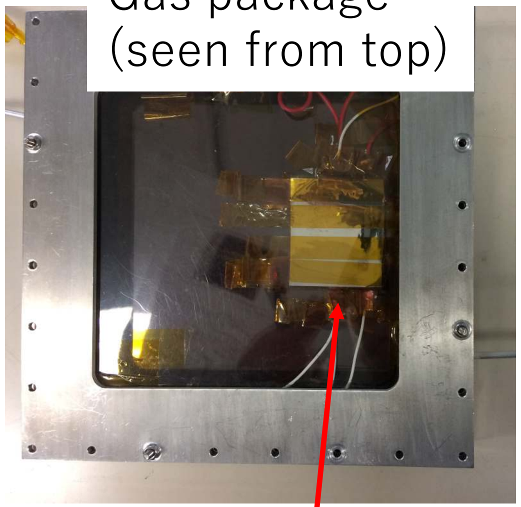
Contents

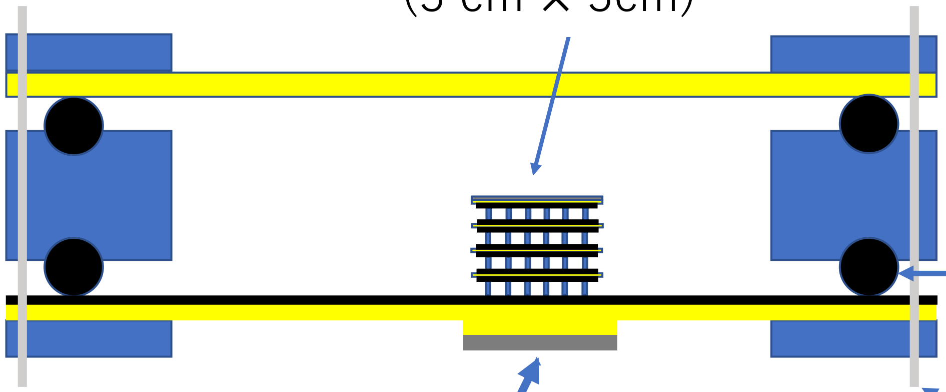
- Introduction
- Development of ultra-low material RPC
  - Prototype design
  - Performance measurement
- Summary and prospect

Prototype detector for performance study

- Size: 3 cm× 3cm

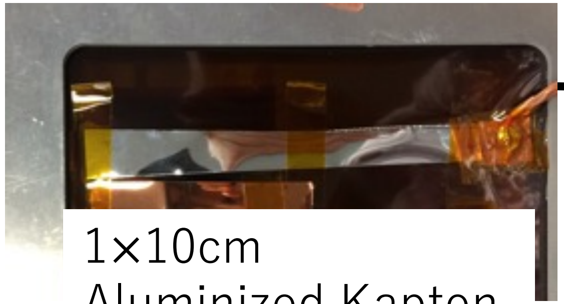
Gas package (seen from top)





gas :R134a/SF_6 = 93/7

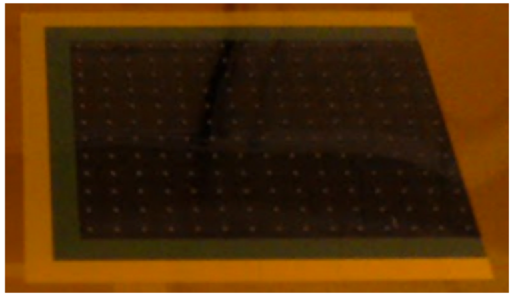
seen from bottom(Al readout)



connected to 38 dB amplifier

1×10cm
Aluminized Kapton
(100nm thick)

3 cm



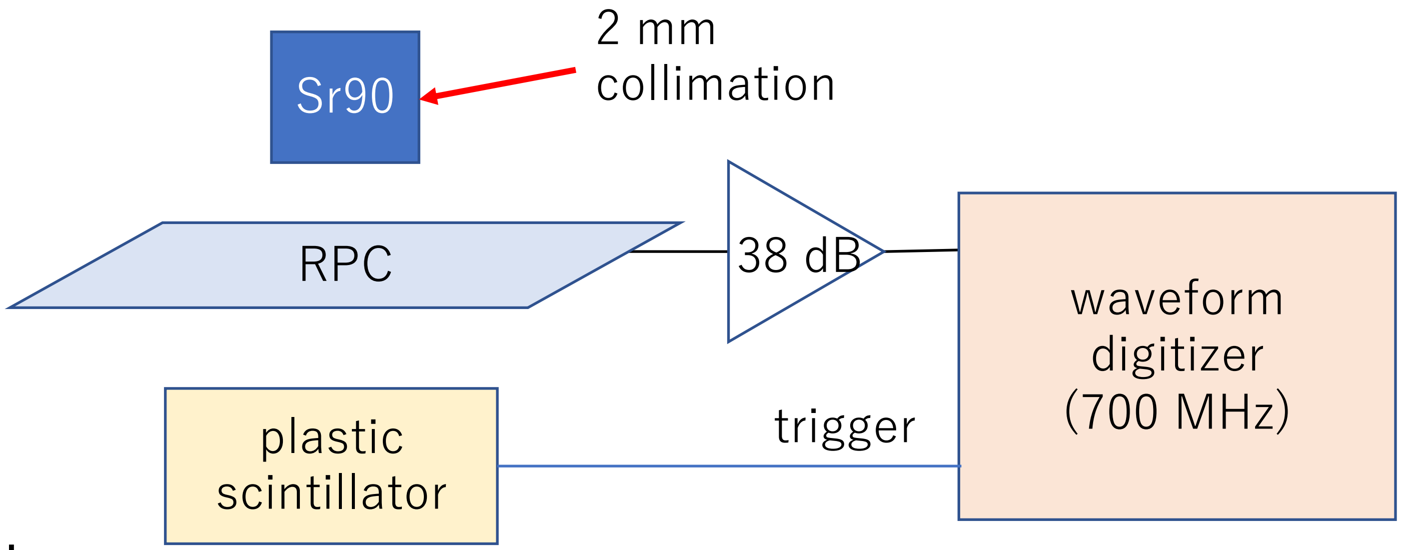
3 cm

resistive plate

Successfully assembled low material prototype detector

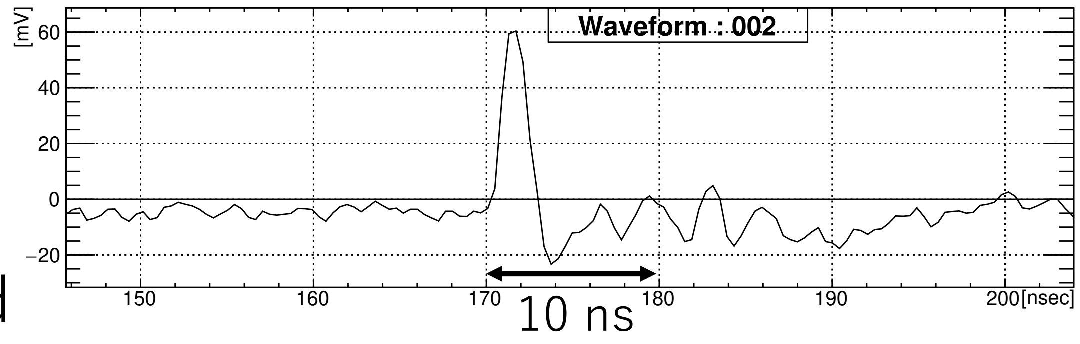
Performance measurement

- Measurement setup
  - Irradiated from ^{90}Sr
  - Plastic scintillator is used for trigger



- Signal is readout by 700 MHz waveform digitizer (DRS4)

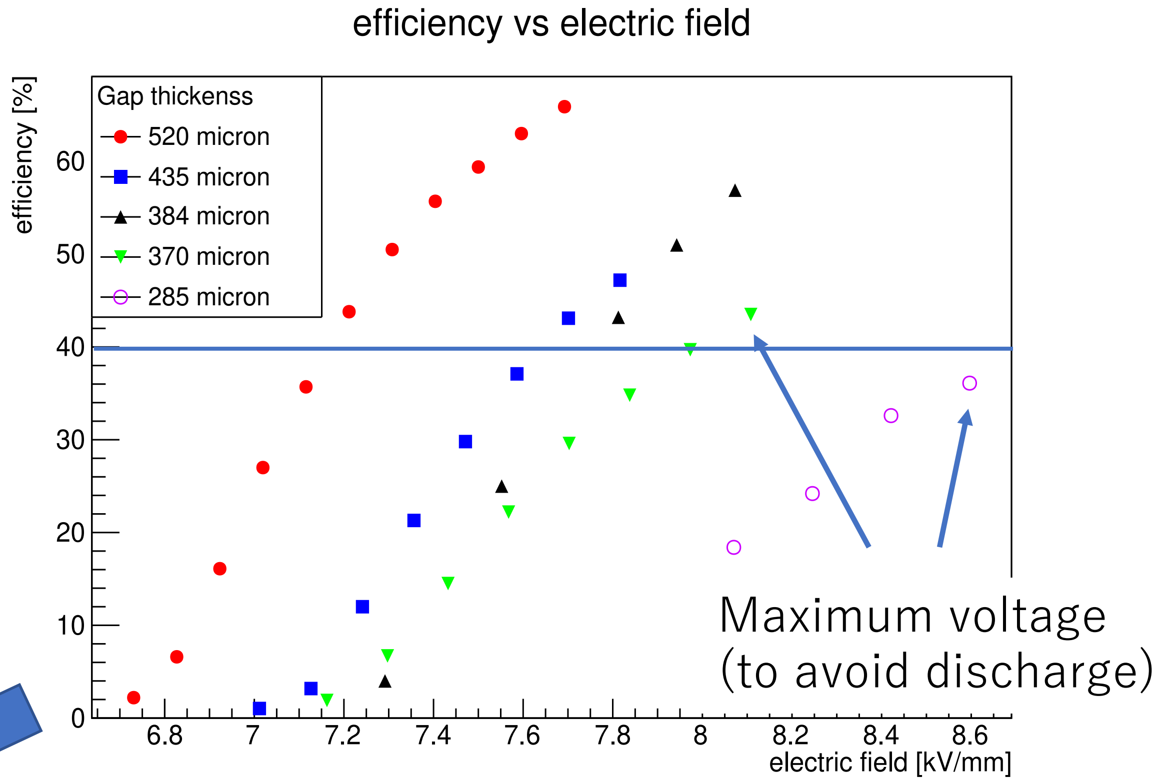
typical RPC signal



- Measurement purposes
  - Check whether the 90% efficiency & < 1 ns timing resolution can be achieved
  - Check optimal gap thickness of RPC

Result: Detection efficiency for single layer

- Single layer efficiency is measured changing the gap thickness
  - 40% single layer efficiency is required to achieve 90% w/ 4-layer
  - $\epsilon_n = 1 - (1 - \epsilon_1)^n$
  - For each thickness, measured changing the operating voltage

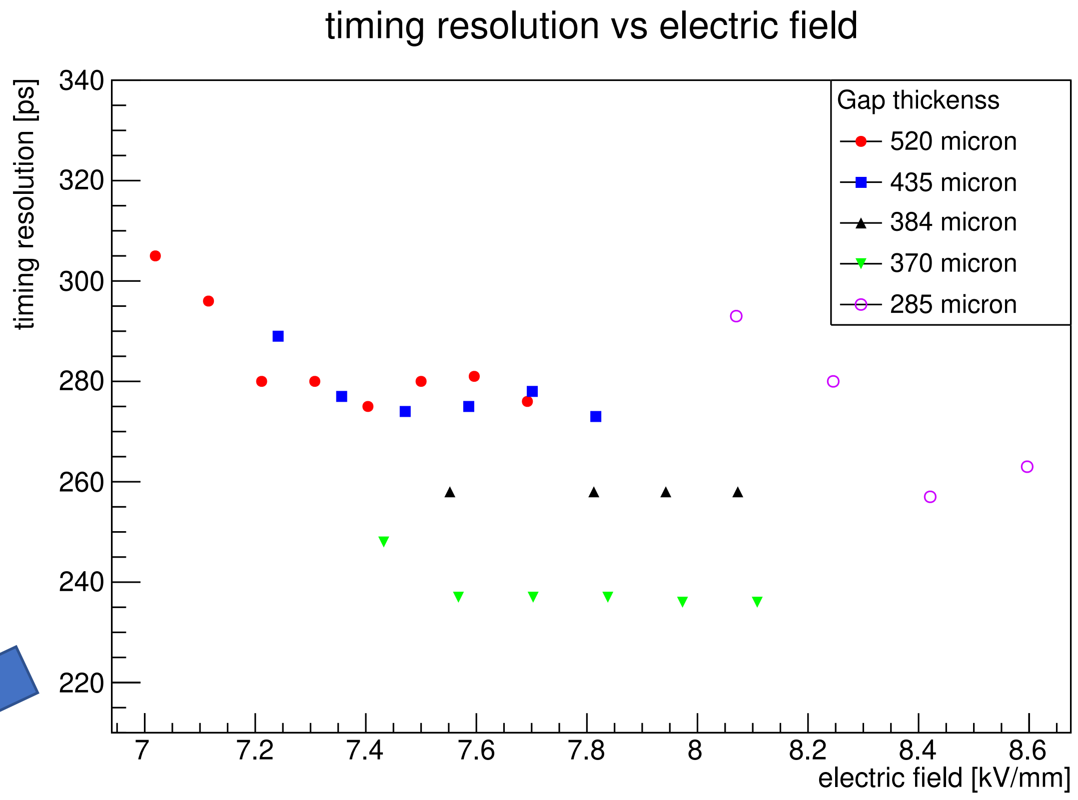


- Efficiency
  - Determined from the fraction of RPC hits in the triggered events
  - RPC threshold = 10 mV

sufficient efficiency for ⩾370 μm thickness

Result: Timing resolution for single layer

- Single layer timing resolution is measured changing the gap thickness
  - (Normally, 4-layer resolution is better)



- Timing resolution
  - Determined from the timing difference b/w RPC and reference counter
  - RPC timing: 50% constant fraction

Timing resolution is good enough at least up to 520μm
(< 1ns required)

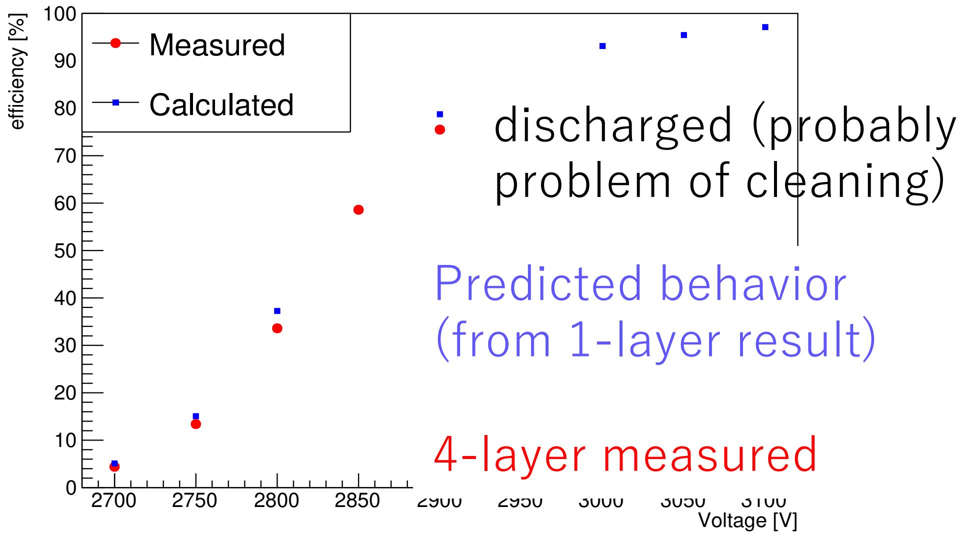
At least, gap thickness can be b/w 370 μm and 520 μm

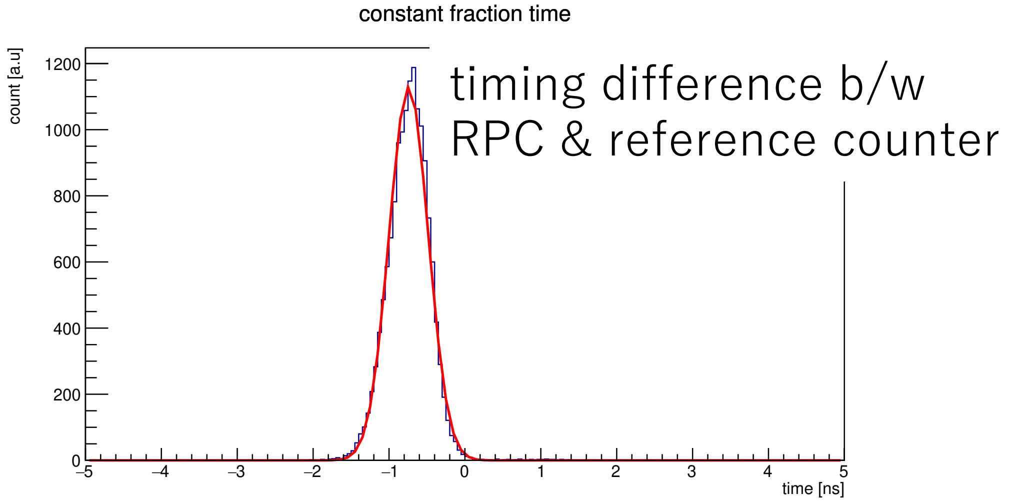
Result: multilayer efficiency and timing resolution

- 384 μm gap 4-layer RPC
- Efficiency
  - Measurement result is compared to behavior predicted from that of single layer
  - Good agreement is seen
- Timing resolution
  - 250 ps

→ Timing resolution and efficiency are good enough

Efficiency vs RPC operating voltage





Contents

Summary

- Ultra-low material RPC is being developed to improve the sensitivity of MEG II experiment

- Prototype studies show that most of the requirements can be satisfied
  - ✓ Material budget: <0.1% X_0
  - ✓ Timing resolution: < 1ns → 250 ps achieved
  - ✓ Detection efficiency: >90% → shown to be reachable

RPC detector is a promising candidate with which the MEG II sensitivity will be improved by 10%

Prospect

- The remaining works are
  - Rate capability measurement
  - Measurement using mu beam
  - Pileup study
    - ➢ Next talk is related
  - Possibility for further detector design optimization
    - ➢ Widening gap thickness to 500 μm is a possible option
    - ➢ Changing the gas mixture (Currently R134a/SF_6 = 93/7 mixture)

    → Careful study is necessary because these parameters affect rate capability and the stability of RPC
  - Construction of full-scale detector (ϕ =20 cm)
    - ➢ RPC itself is scalable in principle
    - ➢ Difficulty for mechanical engineering is expected